Implementation of Photocatalytic Membrane Reactor for Liquid Digestate Sanitation

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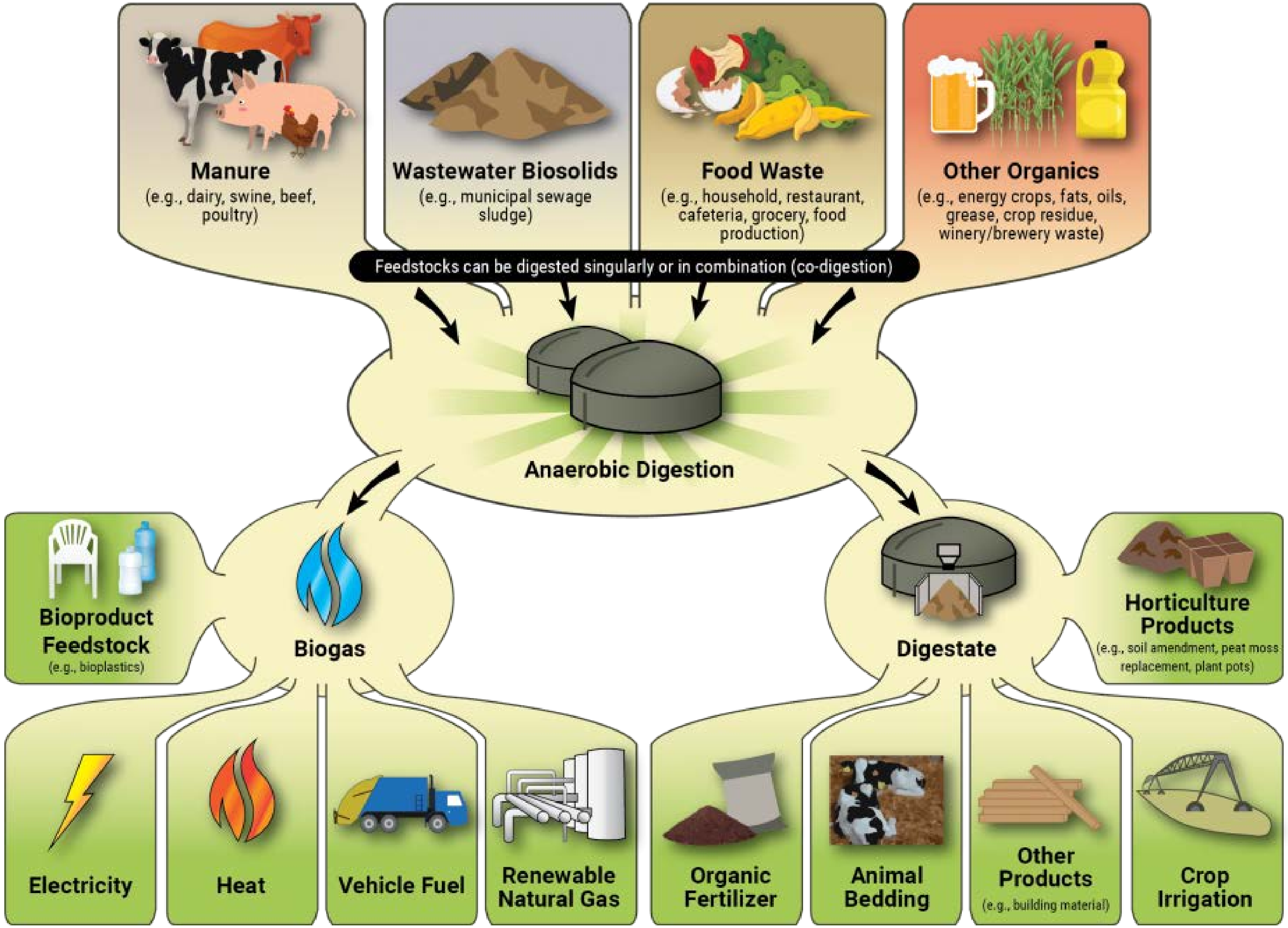
Anaerobic Digestion



https://www.epa.gov/agstar/how-does-anaerobic-digestion-work

Anaerobic digestion

Digestate does not come without sanitation risks

S = S1 * S2 * S3

S1: Ineffective thermal inactivation

S2: Potential transmission pathways (air, water, food, animal contact)

S3: Human health risk

Must be:

- Treated on site
- Disposed in acceptable distances

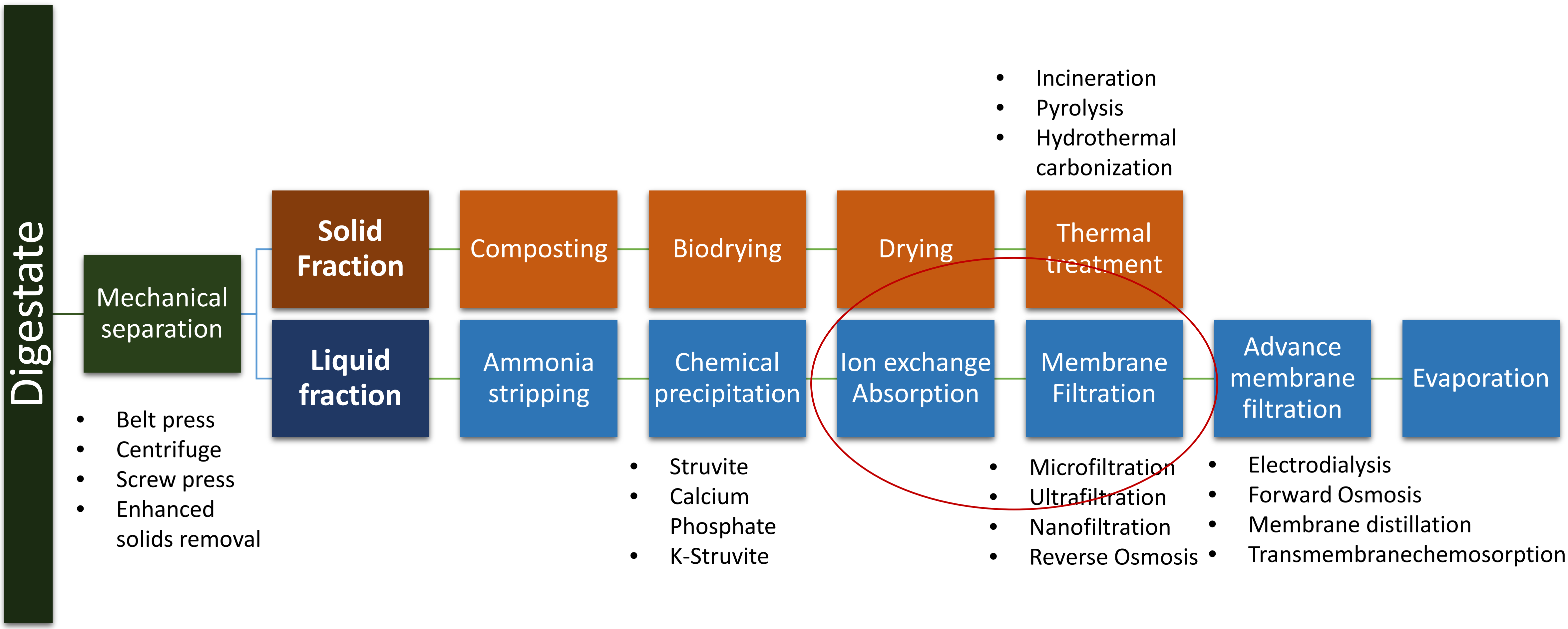
Effective and low-cost new sanitation method

✓ Circular economy

✓ Environment protection

✓ Profitability

Digestate treatment options

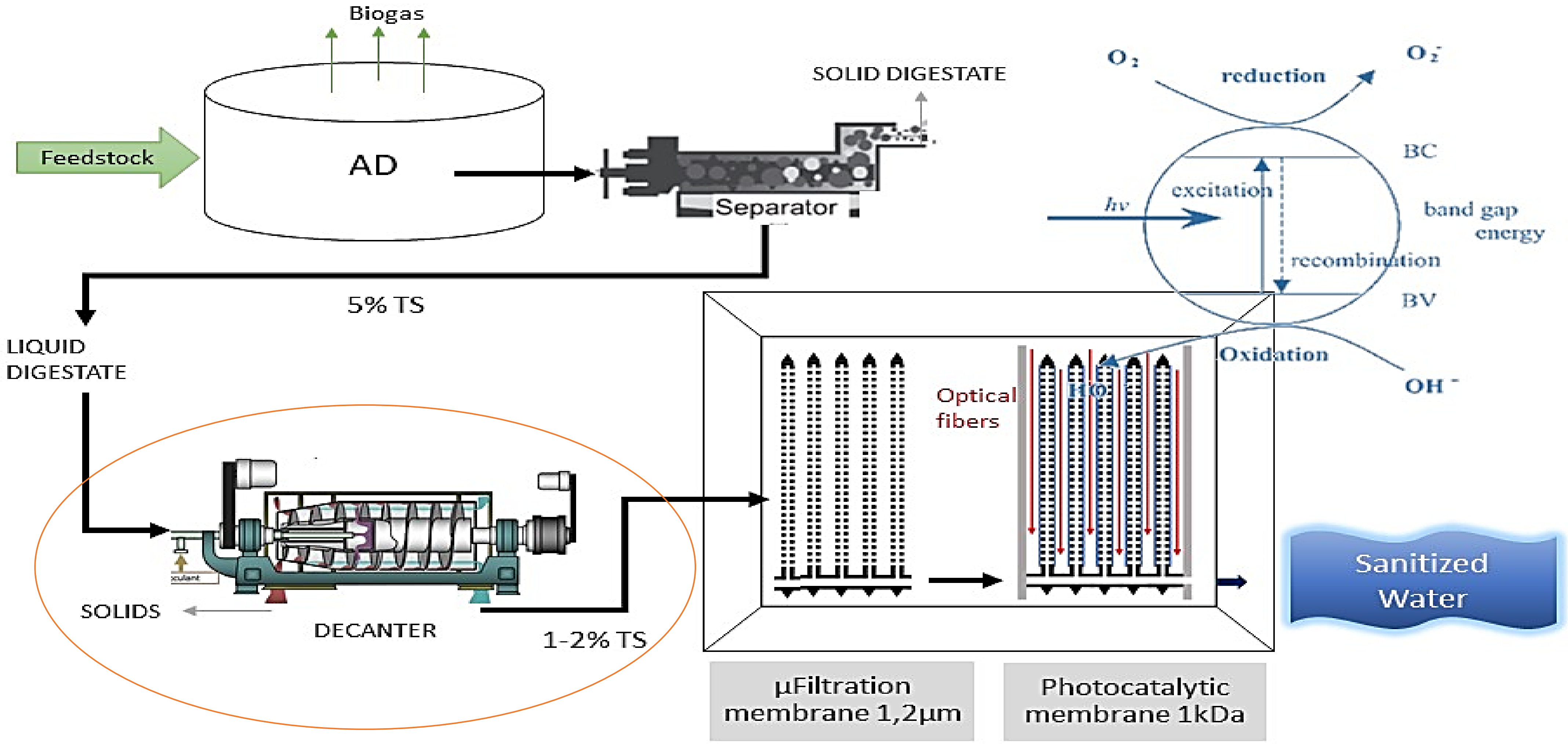


Comparative physicochemical and microbiological characteristics of whole, liquid and solid digestate

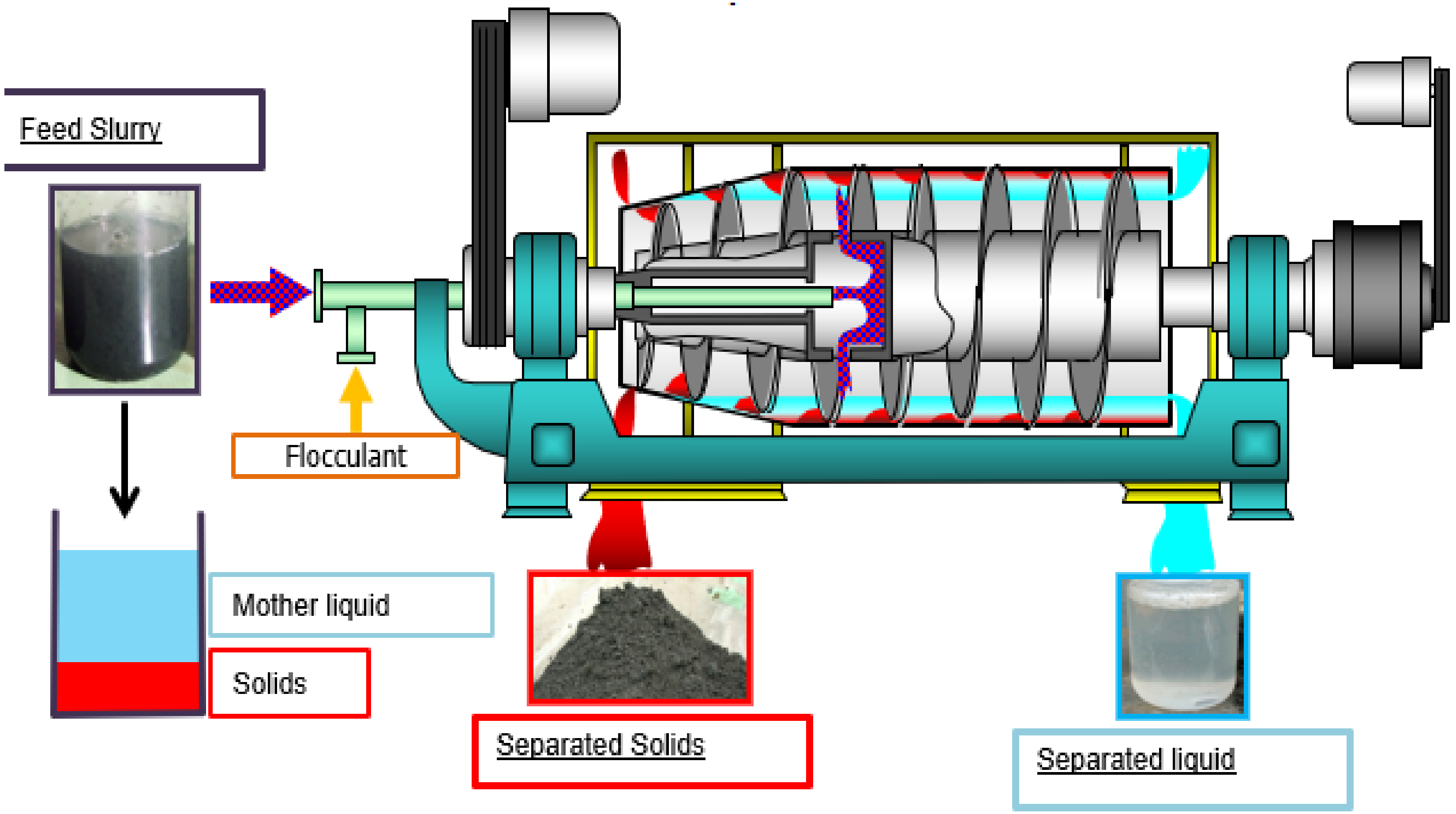
Parameter	Unit	Whole digestate	Liquid digestate	Solid digestate
		mean±sd (min-max)	**mean**±sd (min-max)	**mean**±sd (min-max)
Dry Matter	%	**5.6**±1 (3.9-8.2)	**3.22**±1.6 (1.3-5.8)	**22.5**±7 (11.2-35)
pH	-	**8.1**±0.17 (7.7-8.5)	**8.2**±0.2 (7.9-8.6)	**8.3**±0.3 (6.7-9.4)
Organic Matter	%	**3.78**±0.78 (2.2-5.4)	**1.9**±1.6 (0.7-5.7)	**29**±30.3 (11-87)
Total N	%	**0.5**±0.9 (0.4-7.8)	**0.33**±0.08 (0.2-0.4)	**1.3**±1 (0.5-2.8)
$NH4^+$	%	**0.3**±0.4 (0.02-3.6)	**0.22**±0.06 (0.1-0.4)	**0.4**±0.24 (0.2-0.8)
Total P	%	**0.16**±2.6 (0.06-21.1)	**0.04**±0.05 (0.01-0.1)	**0.9**±1.1 (0.2-3.3)
Total K	%	**0.4**±0.8 (0.03-6.6)	**0.24**±0.08 (0.1-0.4)	**0.57**±0.61 (0.1-1.7)
Ca	%	**0.15**±0.2 (0.06-1.7)	**0.044**±0.05 (0.01-0.1)	**0.68**±0.17 (0.5-0.9)
Mg	%	**0.03**±0.09 (0.003-0.6)	**0.04**±1.9 (0.007-5.1)	**0.23**±0.07 (0.1-0.3)
Na	%	**0.13**±0.05 (0.004-0.2)	**0.09**±0.03 (0.07-0.2)	**0.06**±0.03 (0.01-0.1)
Cl^-	%	**0.22**±0.06 (0.1-0.3)	**0.35**±0.39 (0.1-1.2)	**0.14**±0.07 (0.03-0.2)
Zn	mg/kgDM	**403**±154 (155-1020)	**504**±374 (209-1220)	**144**±83 (50-318)
Cu	mg/kgDM	**129**±93 (24-343)	**197**±135 (59-449)	**73.4**±36 (28-139)
Salmonella	-	**11.1% presence**	**6.7% presence**	**14.3% presence**
E. coli	cfu/gr	**295**±6233 (<10-30000)	(<10-13000)	**72**±185 (30est-490)
E. faecalis	cfu/gr	(<40-1.2*10^6)	(<10-250000)	**565**±3014 (120-7900)

- 3-year monthly data of digestate from two Greek biogas plants
- Unstable nature of digestate → wide ranges
- Presence of pathogens
- Presence of organic micropollutans → risk of leaching

Photocatalytic Nanofiltration Reactor (PNFR) - Schematic representation of complete treatment process for liquid digestate



Stage 1 of PNFR



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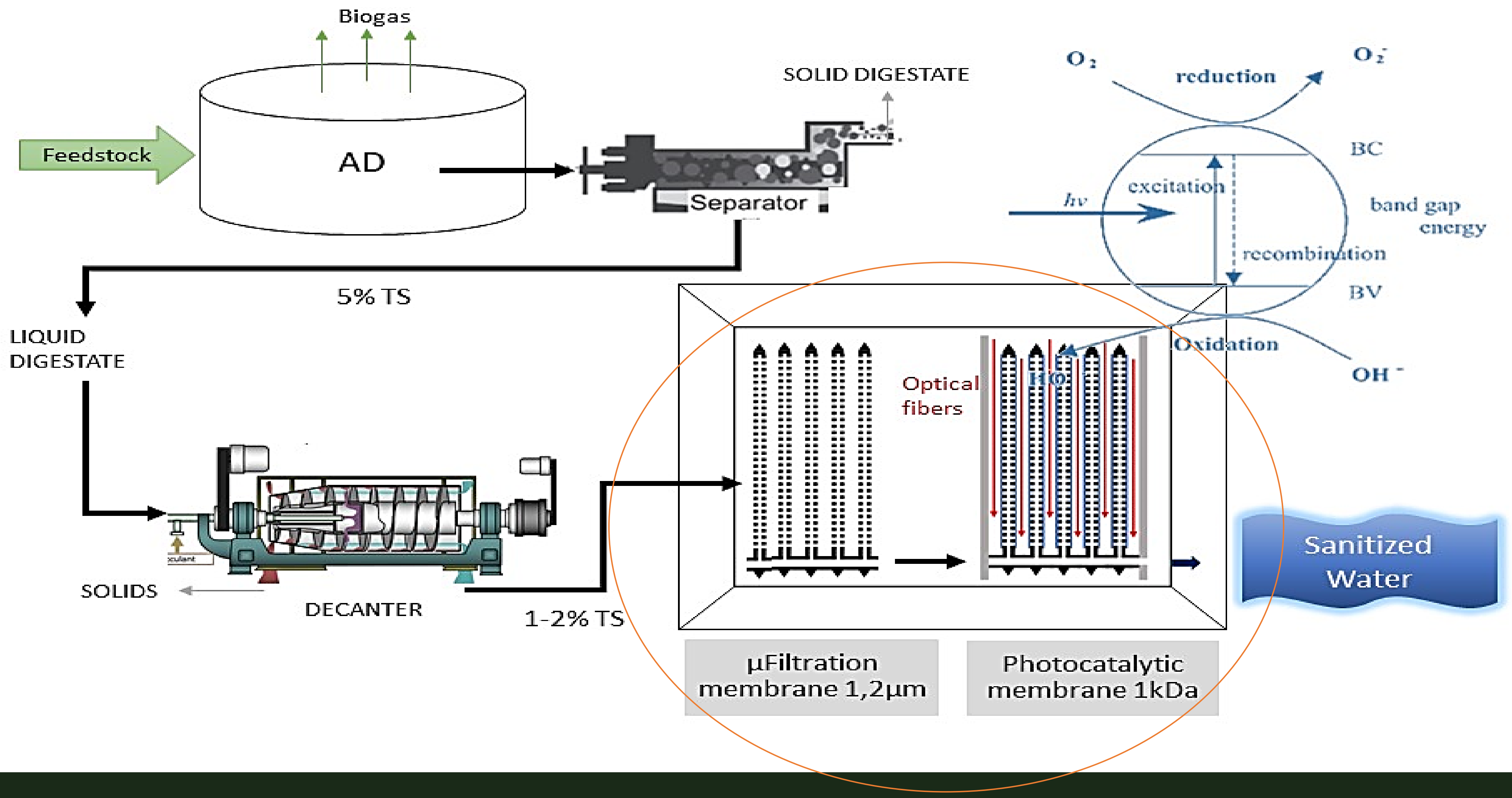
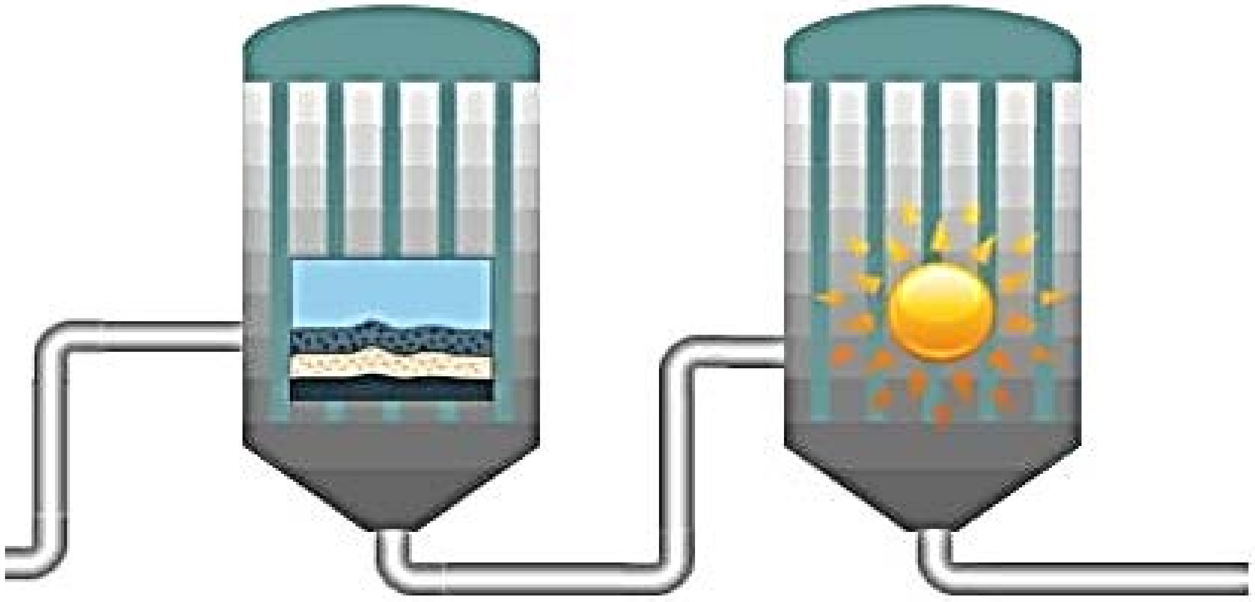
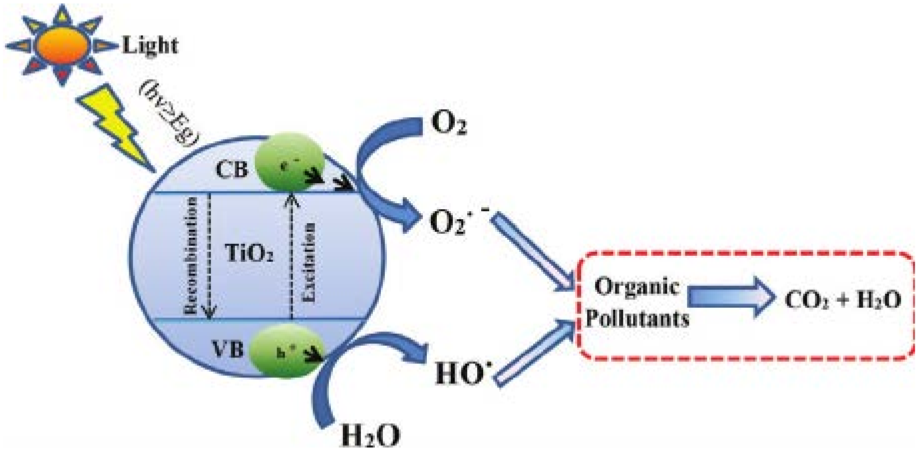


Stages 2 & 3 of PNFR



µFiltration membrane 1.2µm

Photocatalytic membrane 1kDa



PHOTOCATALYSIS

- ✓ cost effective
- ✓ less-energy spending
- ✓ Non-selective oxidation of contaminants
- ✓ simultaneous bactericidal impact
- ✓ chemical-free

Description of PNFR

A Photocatalytic Nanofiltration Reactor (PNFR) where, nanofiltration and photocatalysis act simultaneously and in a synergetic way, overcomes individual drawbacks and cope with the complexity of the aqua matrices independently of their source.

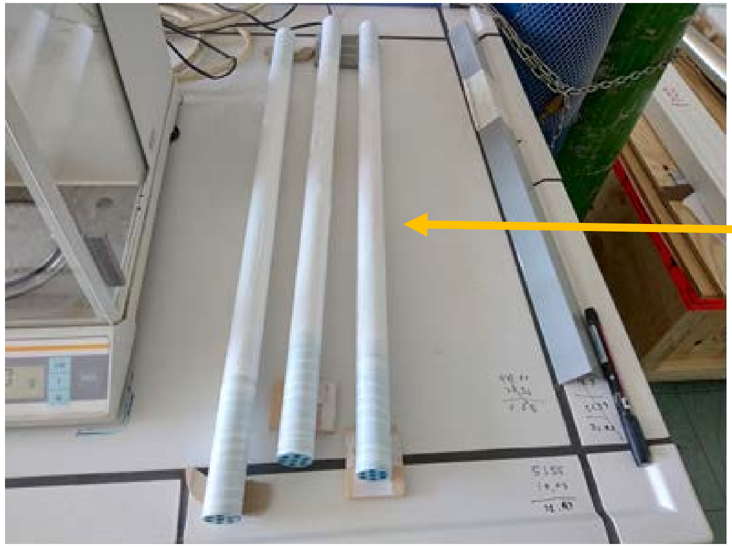
Limitation of Nanofiltration as a stand-alone process:

- Conventional Nanofiltration processes generate a retentate effluent more concentrated than the feed
- Toxic micropollutant that must be managed and disposed with special and costly approaches
- Nanofiltation alone cannot reject the multitude of compounds classified as micropollutants

Limitation of Photocatalysis as a stand-alone process:

- Photocatalysis, usually applied in the from of ultra-thin photocatalytic coatings stabilised on light transparent substrates and get involved in continuous flow processes → Nanoparticles separation
- Mass transfer limitations, poor mixing and short contact times lead to moderate photocatalytic degradation performance
- Competitive action of organic matter that usually exists in industrial effluents

Description of PNFR



600 mm length monoliths (membranes) after dipping in the wash coating slurry of TiO2.

Glass sleeve of the UV lamps

SS-flanges (2 top and 5 bottom)

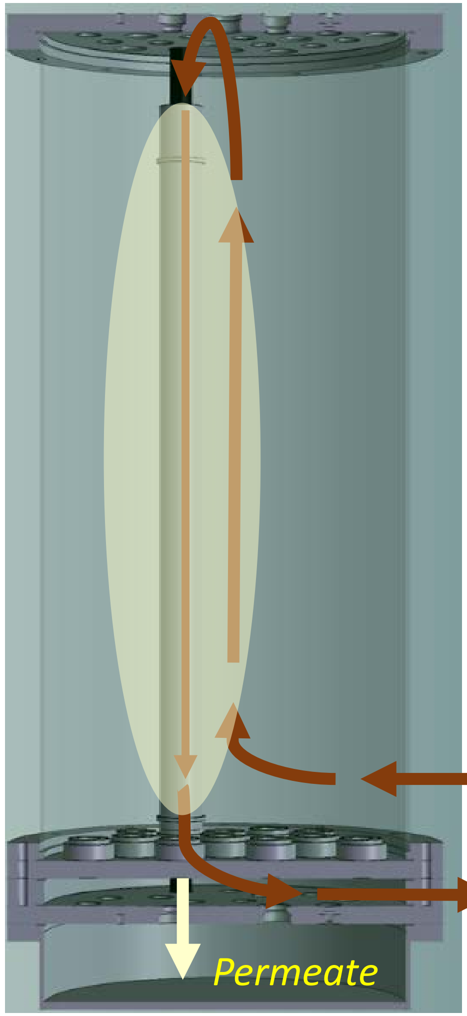
Glazed end of monolith

Perforated ring to hold the TiO2 based mixed matrix fibers

Glass tube around the monolith introducing additional flow channel

Retentate

Side view

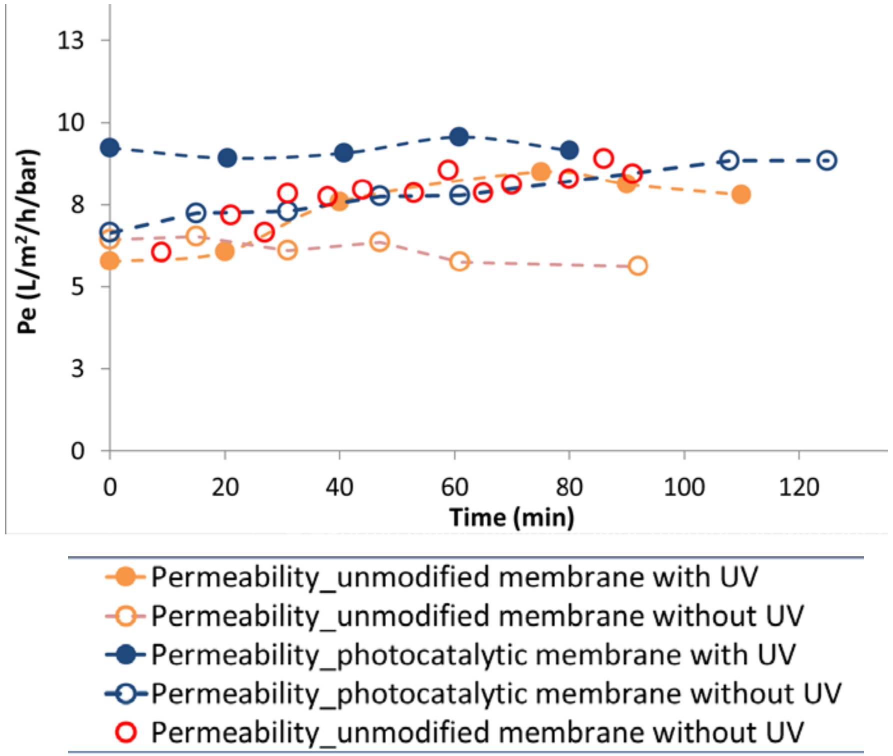


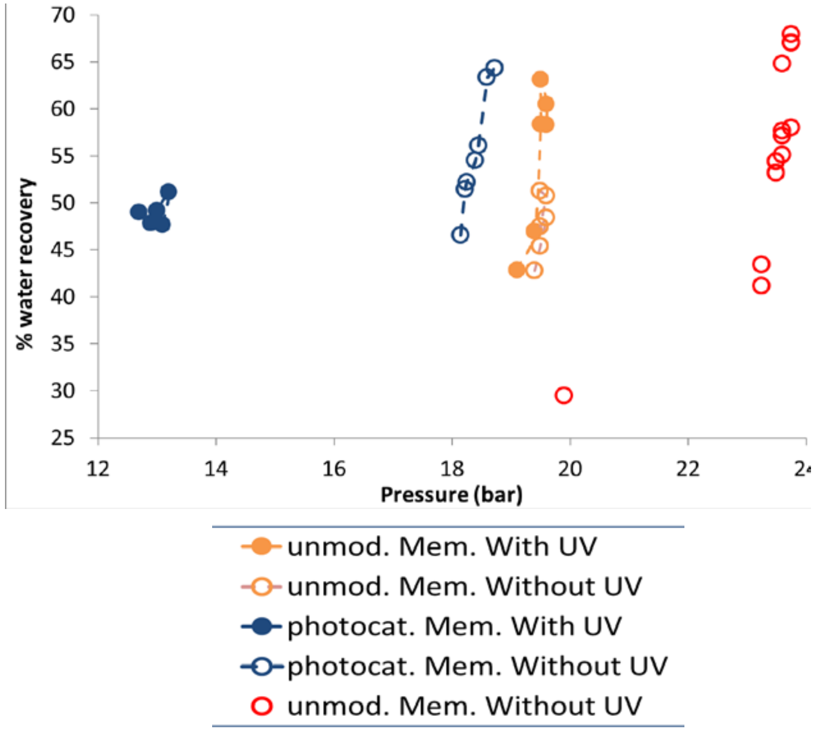
Liquid digestate

Retentate

Cross section of side view

Preliminary Results

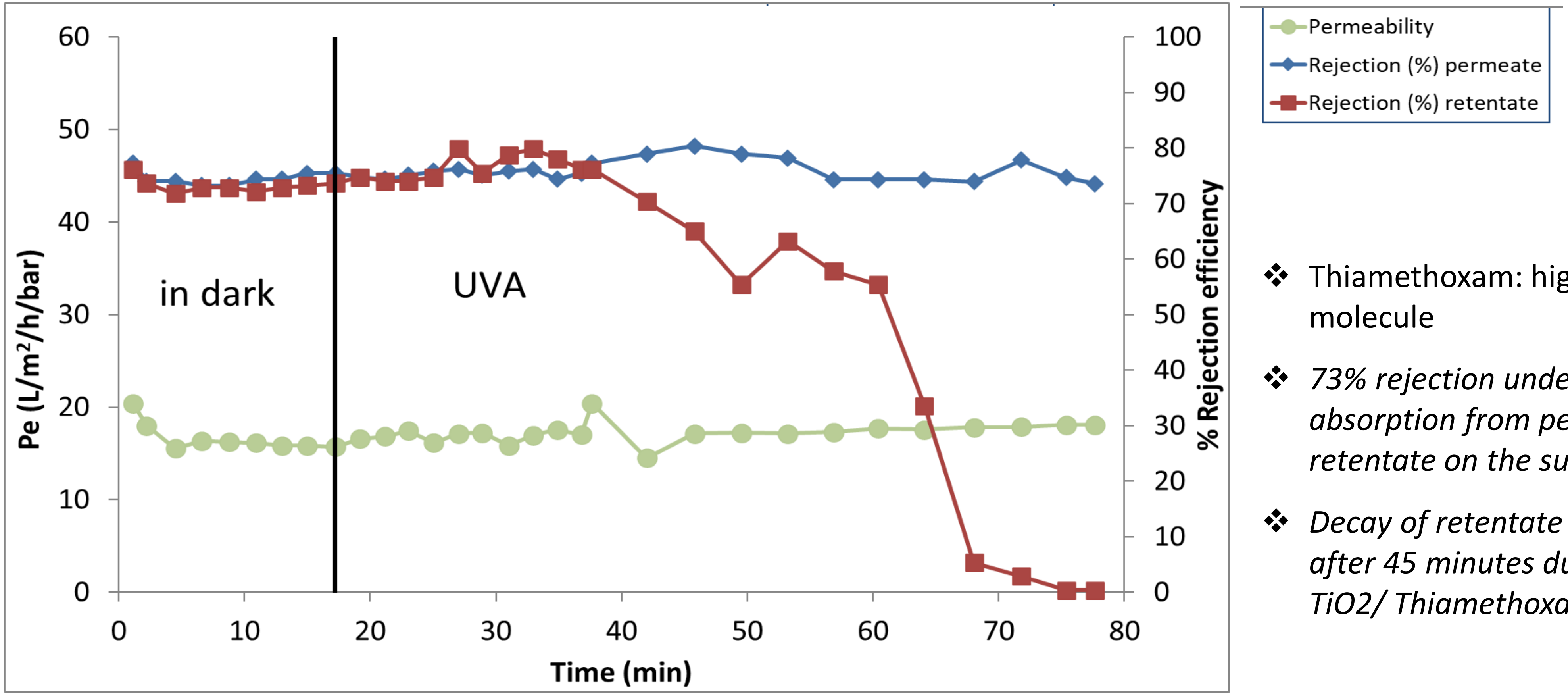




- Permeability properties are not affected by photocatalytic coating of the nanofiltration membrane
- ***Preservation of membrane productivity and extended life span***

- *Clean water recovery of 50% can be reached at about 13.5 bar of transmembrane pressure*
- ***>30% reduction in energy consumption of the photocatalytic nanofiltration process***

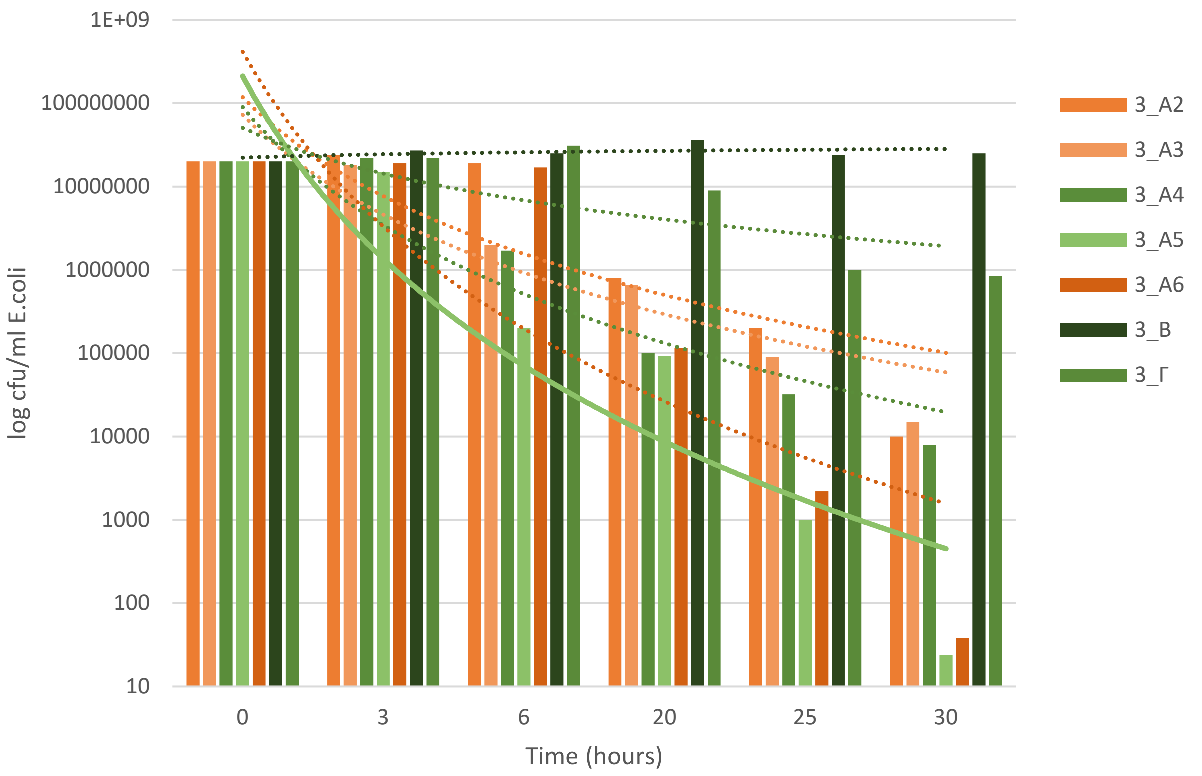
Example of photocatalytic rejection of an organic pollutant



- Thiamethoxam: highly water-soluble molecule
- *73% rejection under dark due to absorption from permeate and retentate on the surface of membrane*
- *Decay of retentate rejection efficiency after 45 minutes due to ~20 mass ratio TiO_2/ Thiamethoxam*

Conventional nanofiltration and photocatalytic nanofiltration experiment with a Thiamethoxam feed solution of 28 ppm. The vertical line corresponds to the initiation of the photocatalytic nanofiltration experiment

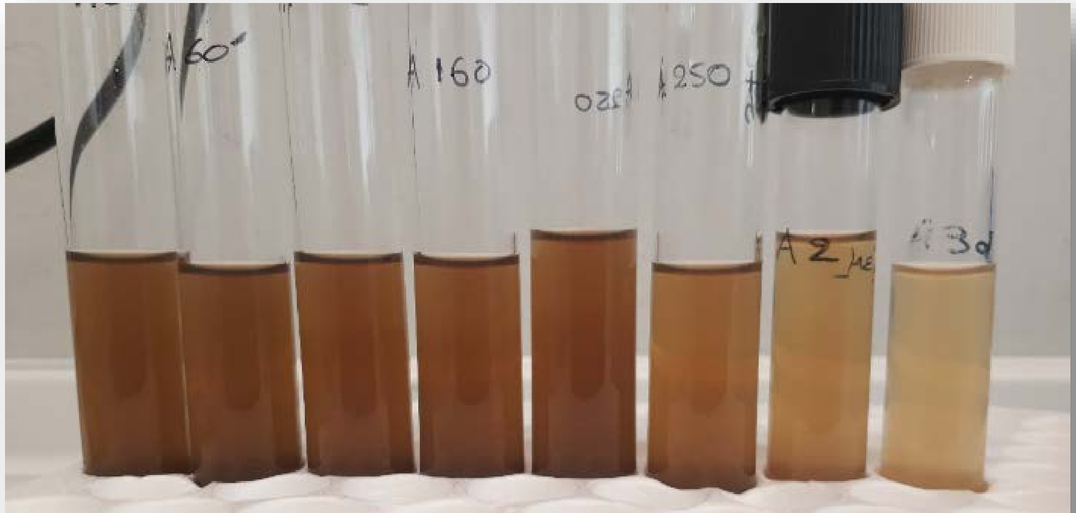
Photocatalytic disinfection of pathogens



3_A: *Different concentration of P25 under UVA*

3_B: *Maximum concentration 0,6 g/L P25 under dark conditions*

3_Γ: *Without P25 under UVA*



Stages of liquid digestate treatment with photocatalytic process

- Synthetic waste inoculated with 10^7 cfu/ml E. coli.
- Photocatalysis dilution with 0,2- 0,6 g/L P25 under UVA.
- Disinfection 3 log observed after 25 hours of photocatalysis on sample 3_A5 0,5 g/L P25

Conclusions and future perspectives

- The implementation of the complete treatment process led to absence of pathogens and pollutants, reduction of COD by 86% , and increase of purity and transparency
- Photocatalysis as final sanitation stage in AD is efficient with economical and environmental advantages
- Industrial application of photocatalytic nanofiltration reactor on liquid digestate seems to overcome the drawbacks of digestate application on field

- Testing the photocatalytic nanofiltration reactor on real samples of liquid fraction of digestate from different AD plants
- Testing sanitation efficiency on different pathogens (E.faecalis, C. perfringens, Thermotolerant viruses)
- Scale up

Partners

Biogas Lagada S.A.

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